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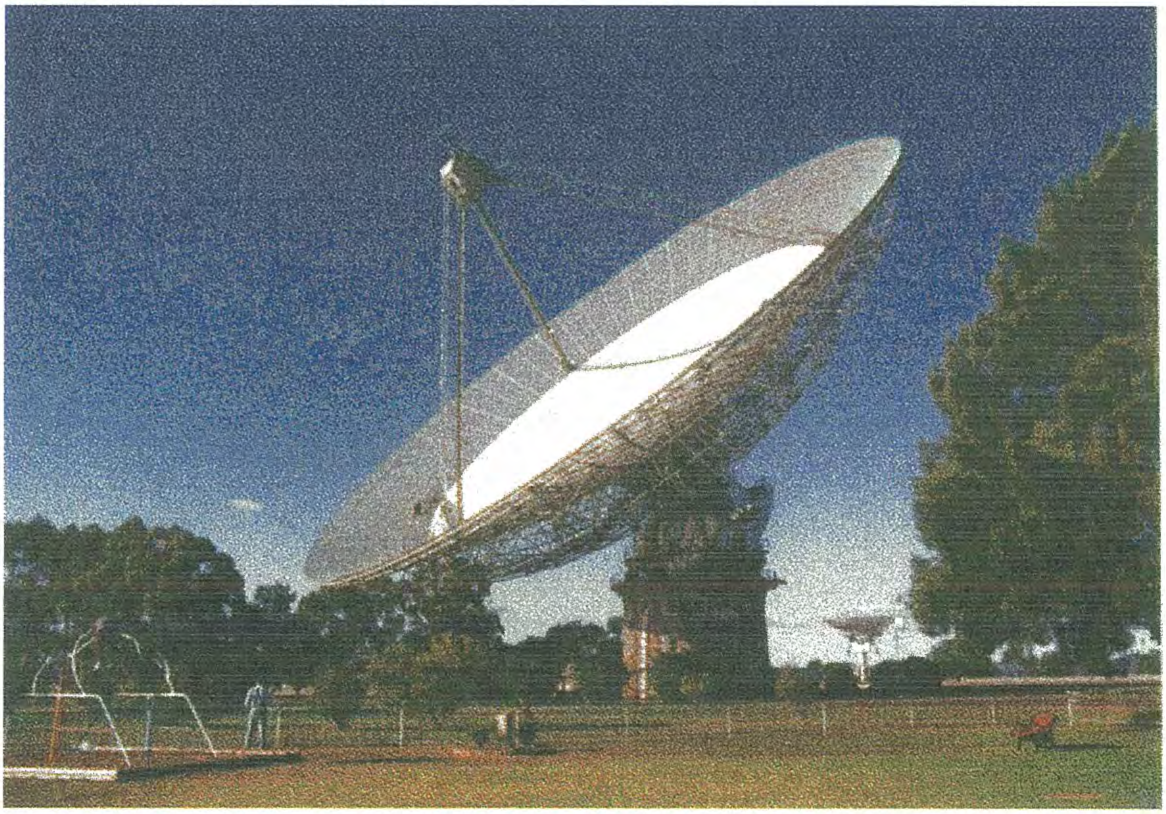
Submission to the Institution of Engineers, Australia
to nominate the

PARKES RADIO TELESCOPE

as a

NATIONAL ENGINEERING LANDMARK

15/10/1995



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INTRODUCTION

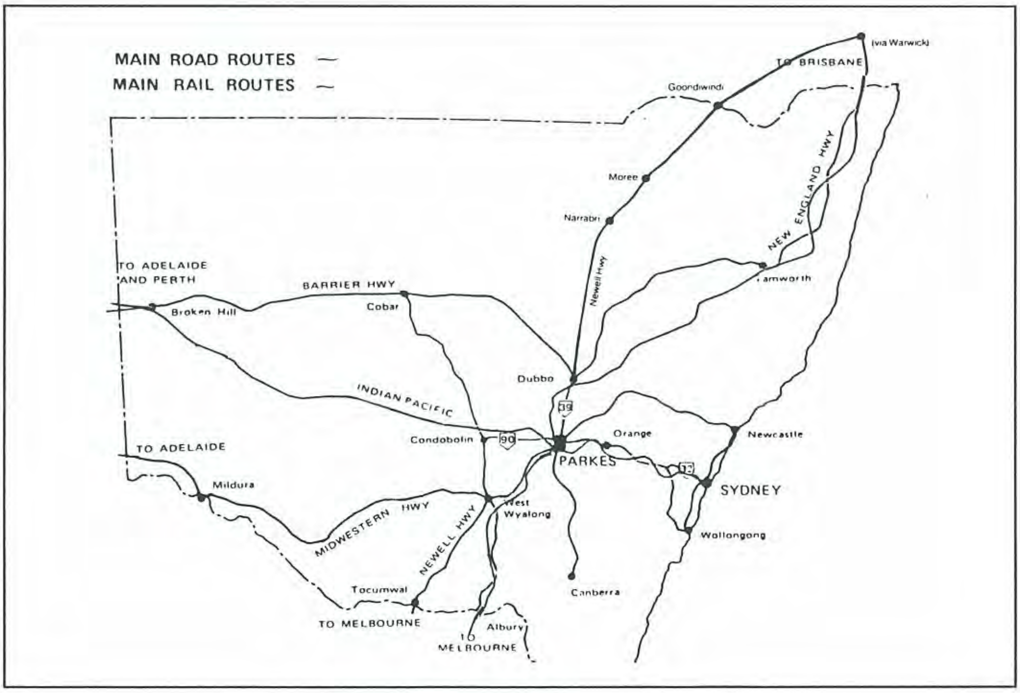
The Parkes 64-metre Radio Telescope is one of the most successful scientific instruments of its type. It was conceived by the late Dr E.G. (Taffy) Bowen, Chief of the CSIRO's Radiophysics laboratory in the 1950s. Australia lead the world in the field of radio astronomy at the time, with important research being done at observatories at Dover Heights and Hornsby in Sydney, Dapto south of Sydney and Pott's Hill and Fleurs to the west. As became clear that bigger telescopes would be needed for greater sensitivity and resolution, located outside of the city to avoid electrical interference, Taffy was convinced that a giant, fully-steerable antenna was the solution. Not everyone agreed, but the verdict of history has proved him correct.

LOCATION:

The 64 metre dish of the Parkes Radio Telescope is located some 20 km north of Parkes, in Central West NSW. Within 6 kilometres of the busy Newell Highway, it attracts the attention of many motorists as they travel between Victoria and Queensland.

GRID ZONE: 55H 100km square ident: FD Reference: 179480

33° 00' South latitude, 140° 18' East longitude



STATEMENT OF SIGNIFICANCE

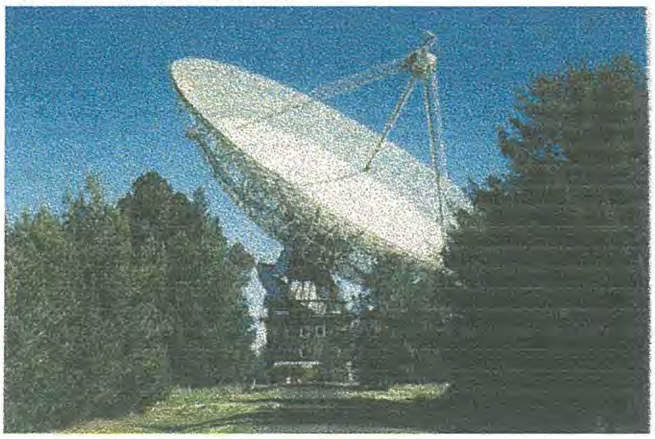
The Parkes Radio Telescope is one of the world's great research instruments, part of CSIRO's contribution to the international science of astronomy. Erected in 1961, it created immediate interest within Australia and excitement in the astronomical and engineering community abroad (refs 1,2). Over a thousand research publications, a number of them landmark papers, have come from observations at Parkes, greatly affecting the world's astronomical community (refs 3,4,9). Excellent engineering enables the Parkes Radio Telescope to remain at the fore-front of the world's radio astronomy, over three decades later. It is "One of the great instruments of modern science", writes Sir Bernard Lovell in the foreword to ref (9).

The Parkes Radio Telescope has become an icon of Australian science: appearing in countless newspaper articles, documentaries and news features, text books and magazines. It was featured on an Australia Post stamp in 1986, and it appears on the back of the current $50 note *(see opposite page).*

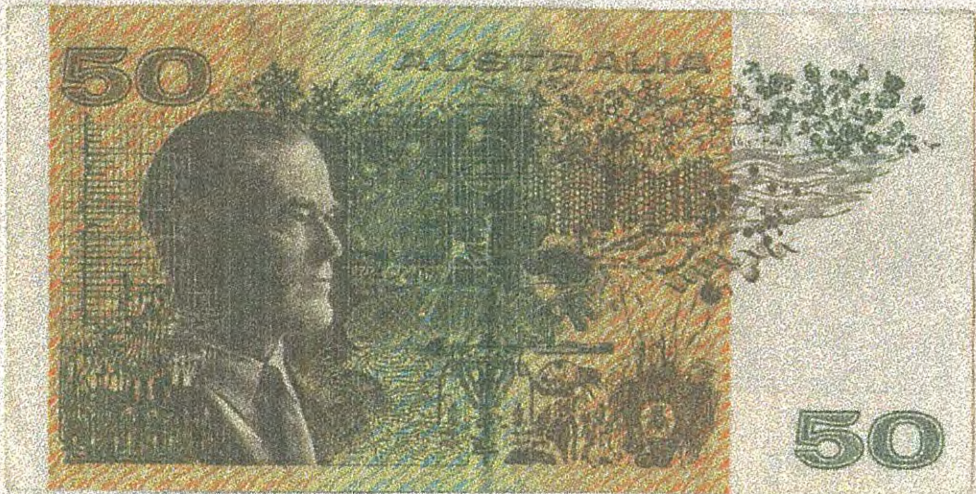
We should also note that of the world's steerable, big-dish radio-telescopes, the Parkes antenna is currently the third-largest, second-oldest and, arguably, the most beautiful due to several innovative design features —some of which, such as the highly innovative altitude-azimuth mounting, have since been copied elsewhere in the world. NASA's Deep Space Network 64 metre antennas were modelled with engineering data from the Parkes antenna (ref 5,6).

Occasional diversions from radio astronomy have substantially added to national prestige, as Australian science and engineering at Parkes were seen to contribute to the success of missions to the moon, planets of the outer Solar System, and Comet Halley.

Over a million curious motorists and many dignitaries have visited the observatory. Comments in the visitor's book reflect the pride of Australians, and admiration of overseas visitors, in such an achievement.



PROJECT PHOENIX launch, Feb 2nd, 1995



Australia Post stamp, 1986

Comet Halley and Parkes' involvement

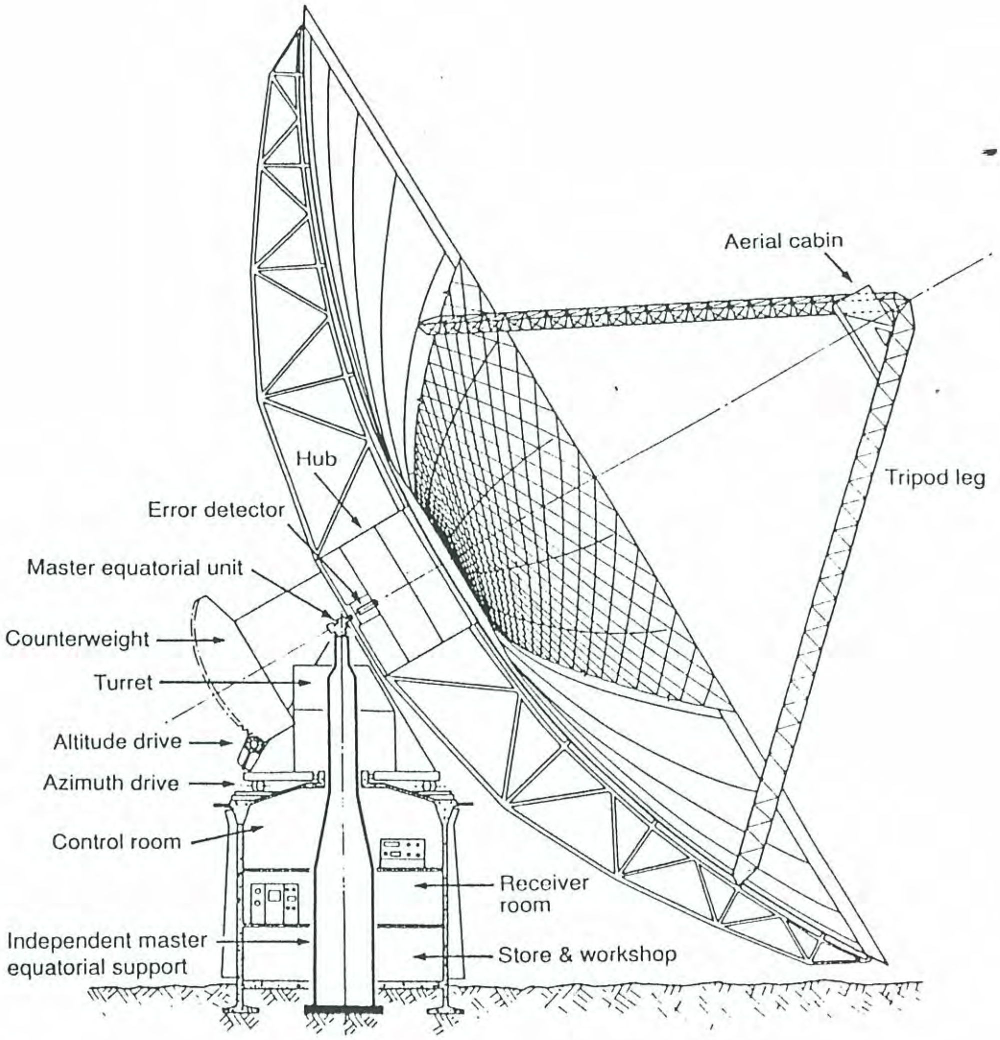
BRIEF HISTORY DESIGN & CONSTRUCTION OF PARKES RADIO TELESCOPE

Specifications for the radio telescope were prepared by CSIRO's Division of Radiophysics. Freeman, Fox & Partners were commissioned to investigate the technical problems involved and advise on a preferred design. Their design study (ref 7) recommended in 1957 an altitude-azimuth mount, which was endorsed by a technical committee convened by Radiophysics. Freeman, Fox & Partners were then asked to prepare a detailed design, and drawings, of an instrument 210 ft (64 metres) in diameter.

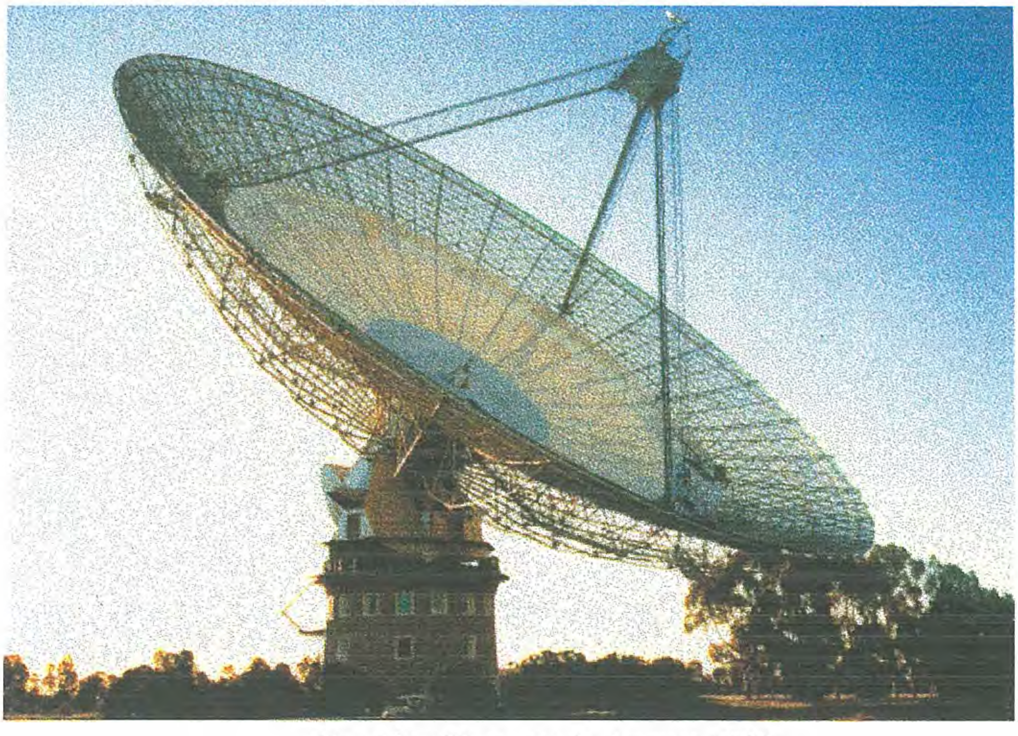
Tenders for construction were invited on a world-wide basis when final drawings had been completed in April 1959. The best bid received, in both price and delivery time, was from the West-German firm of Maschinenfabric Augsburg-Nurnberg A.G (generally known as M.A.N.) M.A.N. agreed to act as prime contractors for the whole structure, with Metropolitan-Vickers of Manchester as sub-contractors to supply the drive and servo-control system, Askania-Werke of West Berlin providing the master equatorial unit (the heart of the control system of the telescope) the error detector and control desk (ref 8), and Concrete Constructions Ltd of Sydney responsible for the foundations and supporting tower. The contract was signed in July 1959. Construction of the concrete supporting tower began in September 1959 and was completed in February 1960 in readiness to receive the turret and hub structure which had, in the mean-time, been fabricated and test-assembled in West Germany.

The surface of the reflector, or "dish", is supported on 30 radial ribs, cantilevered out from the central hub. The ribs were cut and assembled in jigs on-site and welded at night time when all the parts were at the same temperature. Assembly of the ribs on the hub was begun in March 1961. The dish was completed by September 1961, and installation of the complex equipment used for driving the telescope was completed just prior to the official commissioning of the telescope on October 31st, 1961.

It is fitting in this document that we include a list of some individuals involved with the design, construction and the making of Parkes Radio Telescope one of the word's best and most beautiful radio telescopes: EG "Taffy" Bowen, Chief CSIRO Division of Radiophysics whose early vision, leadership and contacts brought this great project about, Gilbert Roberts (Chief Designer, FF&P), Mike Jeffery (FF&P), Barnes Wallis (Vickers-Armstrong), Harry Minnett (Radiophysics consultant/liaison to FF&P), John Bolton (first Director), Frank Kerr and John Shimmins, each from Radiophysics, Jack Rothwell (Associated Electrical Industries) Herr Putz (MAN), Herr August (foreman), Herr John (mech.) and Claus Kalweite (elec).



Parkes antenna: structural details



Tracking Voyager 2, August 1989

ASSESSMENT OF LANDMARK SIGNIFICANCE

Innovation and Technological value: In the late 50s, EG "Taffy" Bowen, Chief of CSIRO Division of Radiophyiscs, had established that if the pioneering and highly-influential radio astronomical research of the Division was to be furthered —so far conducted with improvised, war-surplus equipment— then a fully-steerable, big-dish antenna was needed. Such an antenna, located in the southern hemisphere, would explore half the universe for the first time with greater sensitivity and versatility than had ever been done before.

This was to be Australia's first venture into really big science.

Ultimately (the history of which is lucidly detailed in ref 9), the world expected great things from the Australian 210 ft telescope; clearly evident in the optimistic and visionary speeches at the opening ceremonies, 31st October, 1961:

> **Lord de L'Isle, Governor-General of Australia:** "We are happy to be here on such an auspicious occasion to take part in an event of world importance in the scientific field —the inauguration of the most modern and powerful radio telescope in the world. This instrument will attract the attention of scientists the world over and its importance in helping to unravel the secrets of space cannot be overestimated".
>
> **From Prince Phillip, Duke of Edinburgh**: "The development of radio astronomy has been one of the great events of modern science, and the scientists of CSIRO have played a leading part in this important work. Their studies of the sun the exploration of extra-terrestrial space to the remotest parts of the universe have gained the admiration of astronomers everywhere and have brought great credit to Australia.
>
> Today the radio astronomers of Australia are to be rewarded by the inauguration of a magnificent radio telescope which will enable them to penetrate still further the secrets of the cosmos. This occasion marks the culmination of much planning and hard work and I send you my best wishes for the success of your investigations with this new instrument".

The vision of **EG Bowen, Chief CSIRO Division of Radiophysics**, is inspirational:

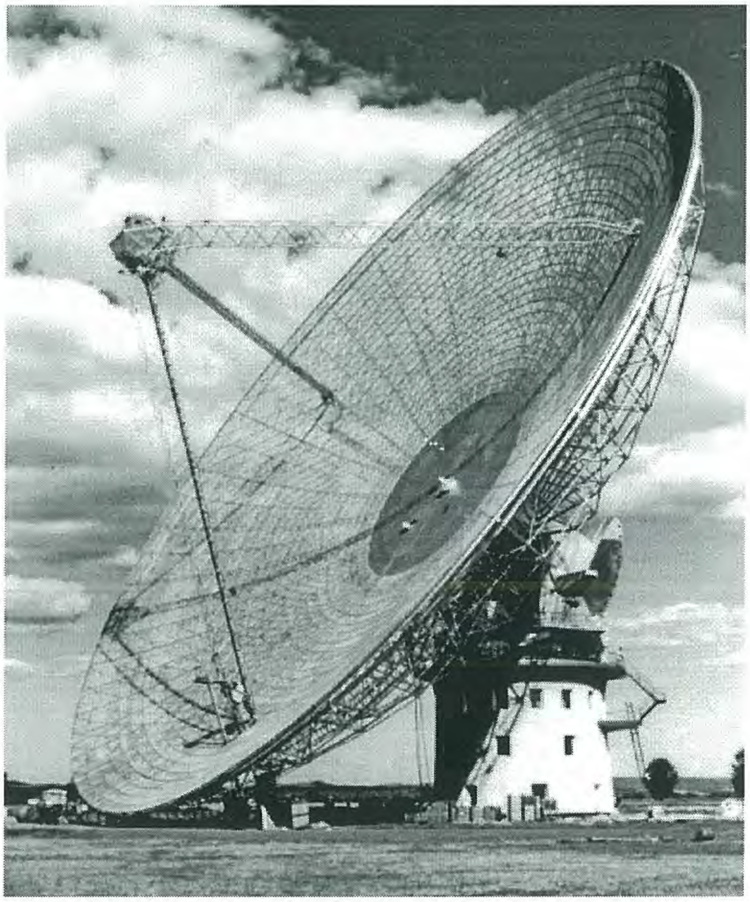
> "Not often in the history of science in Australia are we as highly privileged as we are today in being present at the commissioning of this magnificent scientific instrument —an instrument which is destined to extend our vision and understanding of the mysteries of outer space.
>
> Since the dawn of history, man has gazed at the stars and wondered at the mystery and immensity of the universe. He did this first with his naked eye and then with crude lenses no better than a burning glass. Over the years his understanding has improved and his instruments have become more powerful, culminating in the great 100 and 200 inch optical telescopes of the northern hemisphere.

Only in the past twenty or thirty years have radio telescopes appeared over our horizons, and today, less than ten years after its conception, we have this great 210 foot instrument —unique in the southern hemisphere and with a performance unlikely to be matched for many years to come.

Radio telescopes exist in a bewildering array of types, but this one is regarded as the basic type: it may be steered to any part of the sky, it may be used over a wide range of frequencies and for an infinite variety of astronomical researches. The instrument we have commissioned today is the prime example of its kind in the world at the present time, and for a generation it is likely to remain a key instrument in our search for the ultimate truth about the universe . . .

. . . The existence of this instrument has attracted the interest of our fellow astronomers the world over. When the first urgent tasks of the next few months have been performed, it will be thrown open to astronomers from every part of the world with worthwhile problems to attack. We pledge ourselves to work in close collaboration with our fellow scientists from any country and will make this observatory a rallying point for equipment and information, for techniques and intellects which, together, will lead to further great advances in the science of astronomy".

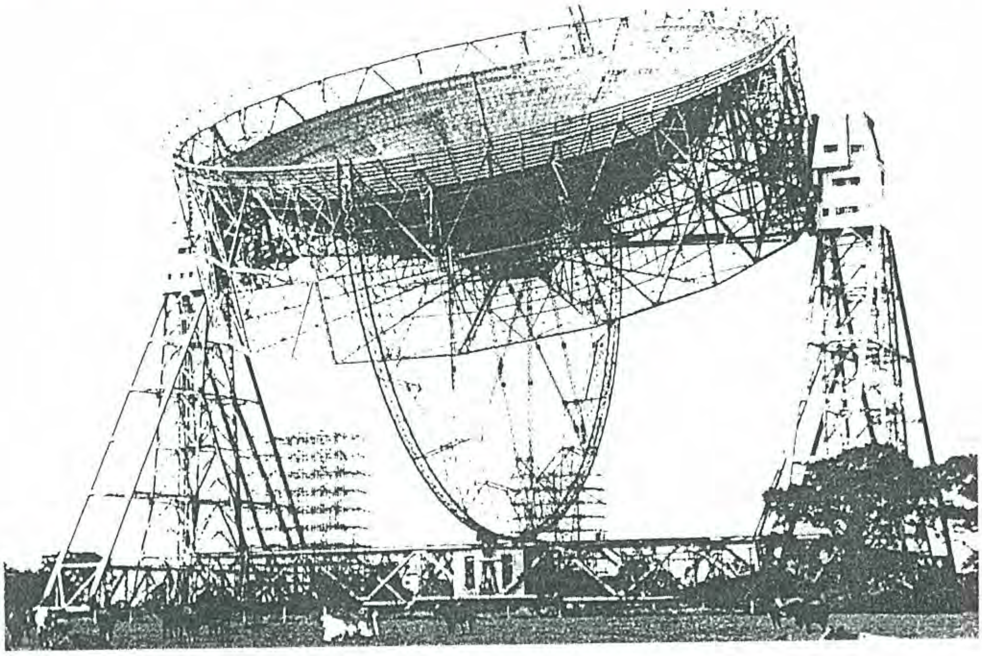
More of Dr Bowen's speech appears in another section of this submission.



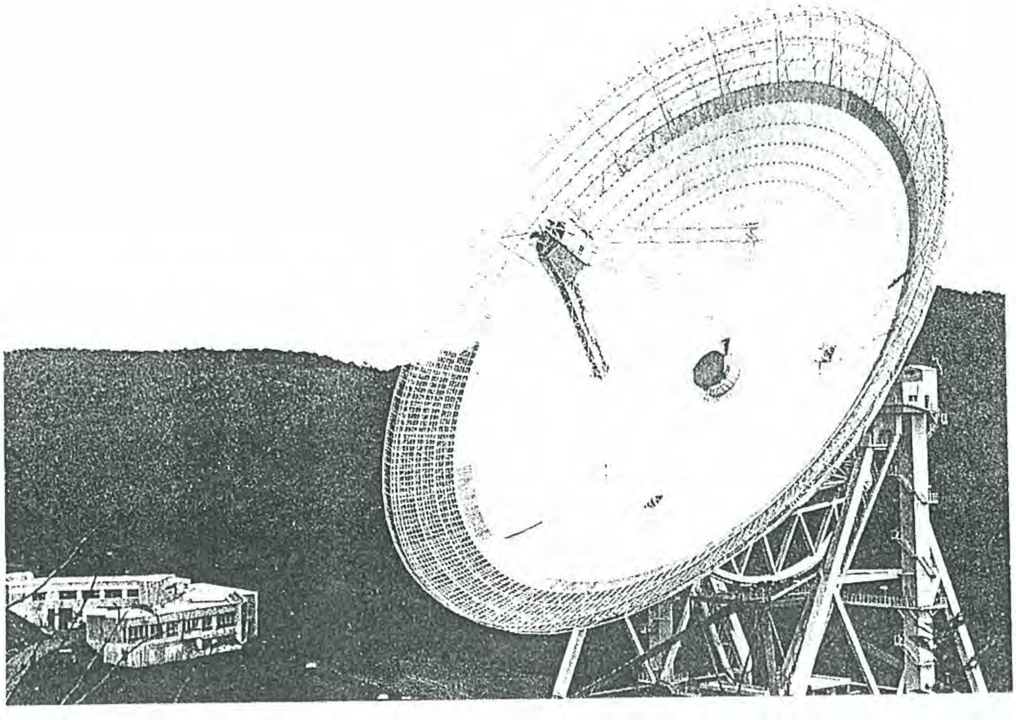
The telescope tilts from the zenith for the first time

Innovative design features, and influence on other structures.

Smaller radio telescopes of the paraboloidal kind, in the northern hemisphere were mounted on polar axes. In 1957 only Jodrell bank, the first really large dish radio telescope ever built and larger than the Parkes dish at 76 metres, was on azimuth-altitude bearings. Pictured below, take note of its support bogeys and complex sub-structures.



Built in the 1980's, the 100-metre Effelsburg radio telescope had a similar mounting system to Jodrell Bank. Also, like Jodrell Bank, the control rooms are 100 metres away, leaving a space in the corresponding position where the control room of Parkes is. During an observing run at Parkes, being just under the dish and accompanied by continual noises of drives to another source, observers tend to feel that the Parkes telescope is "an astronomer's telescope".



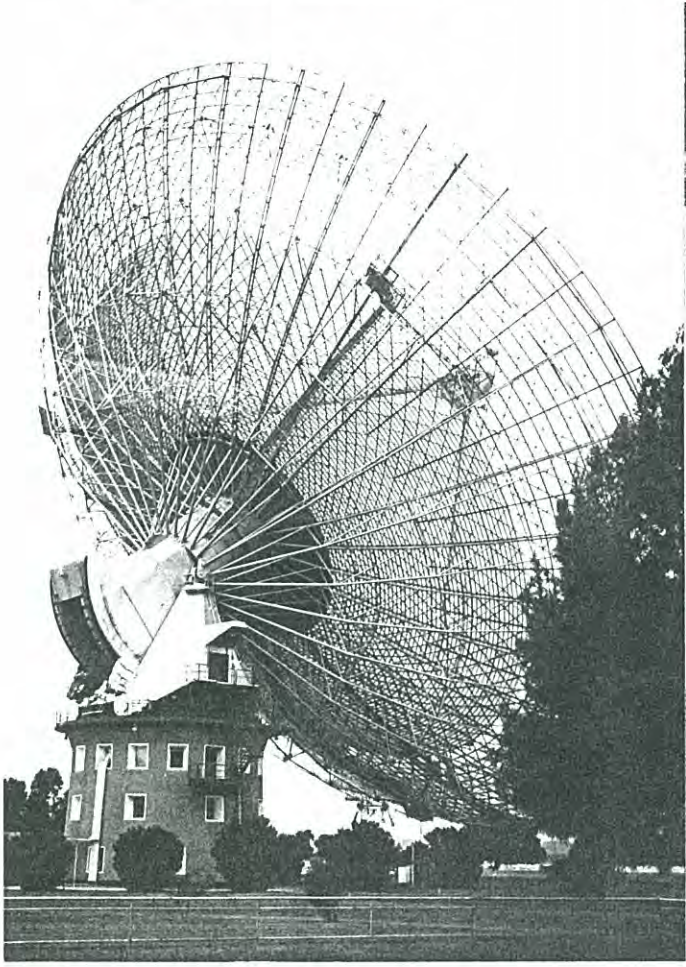
The Parkes antenna is driven in azimuth and altitude too, but has an internally-mounted equatorially-driven "master" to which the big dish is "slave" through an optically-coupled error-detection and servo-feedback system (refs 8,10). The master equatorial, or ME, is located at the intersection of the axes of rotation of the telescope at the suggestion of Barnes Wallis. Servo-system dynamic analysis was by Minnett (ref 12).

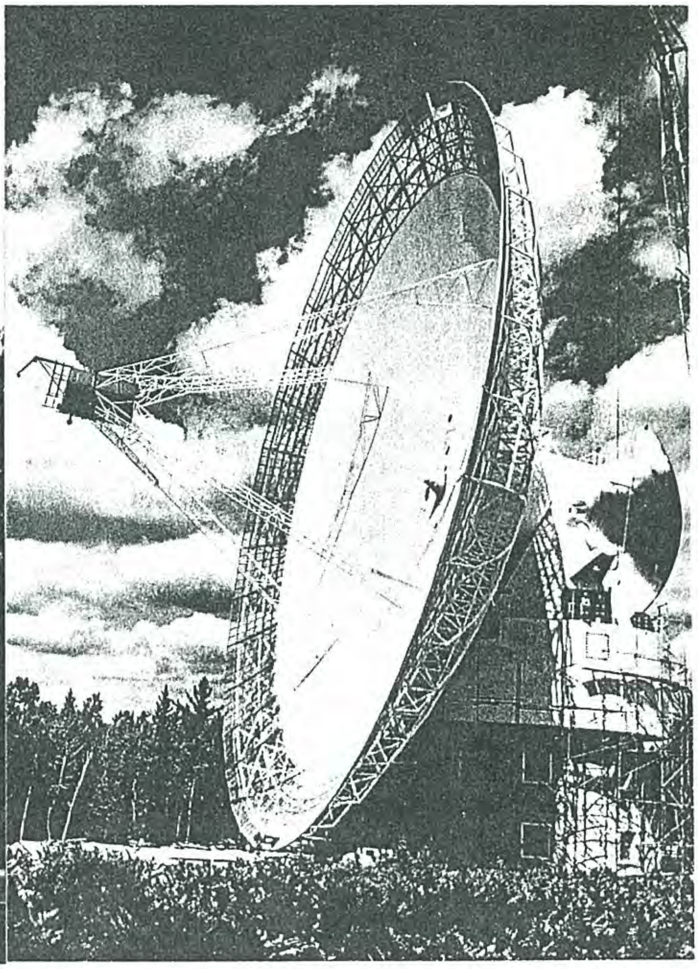
The driving accuracy provided by this superior ME/error-detection system enabled the bearings for the dish support to be located closer to the central axes of the telescope. The counterweight, a natural consequence of this arrangement, produces the net effect that the Parkes dish is elegantly balanced atop a three-storey control room.

The Parkes design and behaviour was extensively studied after its construction. By 1966 over thirty research papers on the telescope's features and performance had been published (ref 9) in engineering and tele-communication journals (refs 1,2,5,6,8,10). This information was freely available to the designers of large dishes elsewhere, and features were in fact duplicated in the forth-coming large antennas of NASA's Deep Space Network at Goldstone, Madrid and Tidbinbilla. Comprehensive vibration analysis (refs 5,6) was funded by a NASA Grant: NsG-240-62.

Inspired by confidence in precise servo-control systems initiated at Parkes, the world's newest optical telescopes also use alt-az mountings — with dramatic reduction in costs. The ANU 2.3 metre telescope (1984) at Siding Spring is one such example.

In Canada, the Algonquin radio telescope (pictured below) is a direct, though smaller, clone of the Parkes dish.





Parkes Algonquin, Canada

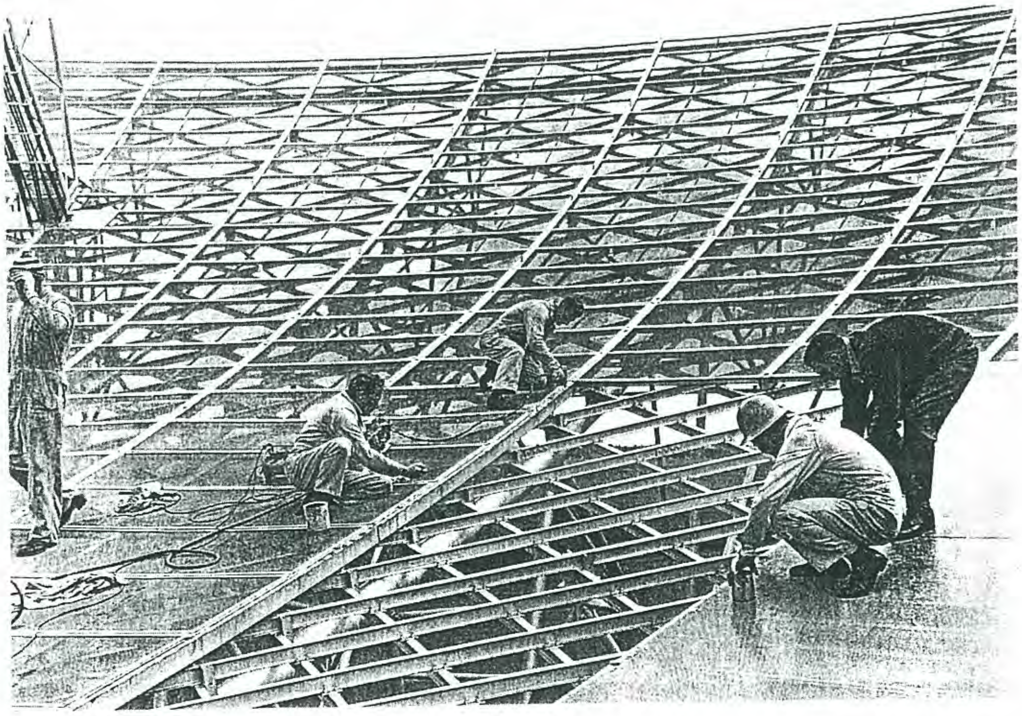
Integrity: pointing accuracy

With gear ratios of 40,000:1 and position upgrades computed every second, the dish smoothly compensates for the Earth's rotation, by night and by day. Initially designed to perform with a pointing accuracy of 1 arc-minute, on the night of the Voyager 2 encounter with Neptune in August 1989, the Parkes antenna did not deviate from the source by more than 10 arc seconds due to newer tracking techniques. The dish is typically subject to pointing errors of about 8 arc-seconds RMS, in average wind conditions. Winds of over 35 km/hr lead to automatic stowing of the dish, in its parked position pointing at the zenith —the orientation with minimum wind loading.

Integrity: surface accuracy

The design specified that the surface errors of the dish were to be within 1/16 of the operating wavelength (refs 1,2,7) which, for the 21 cm line from the neutral hydrogen of interstellar space, was a little over a centimetre. However it was allowed that the errors could be relative to the paraboloid of revolution that best fitted the actual surface resulting from differing distortions at new angles of elevation (hence the incorporation of an adjustable focus height of the receiver in the aerial cabin). Meeting this constraint of precision construction — unprecedented for a dish of this size — would also allow the telescope to work later at an intended 10cm wavelength, and perhaps at smaller wavelengths as the astronomical need became greater, and as afforded by advances in high-frequency amplifier design. The only other large dish at the time, Jodrell Bank, by contrast, was designed to operate at 75cm, and was accordingly not similarly constrained in its surface accuracy.

Subsequent surveys showed that the Parkes surface was, in fact, so free from aberrations that it was feasible to upgrade the surface by re-panelling the inner half of the dish with a more solid surface, to reflect smaller centimetre waves, and later millimetre waves too. This enabled work at higher frequencies and with higher resolution, revealing new astrophysics.



The first reskinning of the Parkes dish took place in two stages in 1970 and 1972. The original wire mesh was replaced by perforated aluminium panels out to a diameter of 37 m. NASA funded the new surface in return for use of the telescope during the Apollo missions. In 1982 the aluminium panels were extended out to a diameter of 44 m, on this occasion by courtesy of the European Space Agency.

The time to survey and adjust the dish surface has reduced to around 5 hours, compared to the tedious and arduous 5 weeks of earlier decades, with a new, holographic technique that uses a pure tone from AUSSAT as a source. In 1994 an ATNF staff member went to the VLA in America to pass on his expertise in this field. For his work he was awarded the 1994 *John Madsen Medal,* by the Board of the College of Electrical Engineers of the Institute of Engineers, Australia. In 1994/95 there is another study to assess the cost/benefits of another up-grade to yet a greater area to the Parkes antenna.

Integrity: Longevity

Originally expected to last around 15-20 years, the Parkes Radio Telescope is now 33 years old. Part of CSIRO's Australia Telescope National Facility, and still at the fore-front of the world's astronomy, Parkes is used as a stand-alone instrument or arrayed with either the 7 smaller antennae of ATNF, or other dishes in Japan, western USA or South Africa for very long base-line interferometry.

This longevity is due largely to its structural integrity, and the advances in electronics and computing which enable new volumes of observational phase-space to be explored.

Social Value: National prestige:

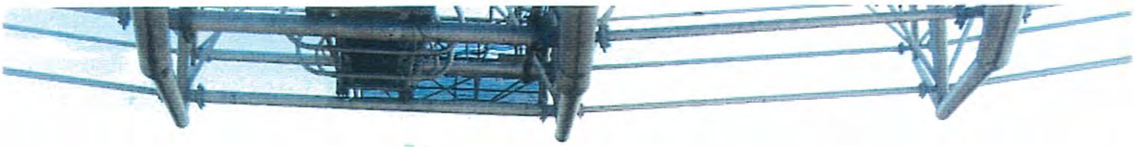
Parkes Observatory is dedicated to the advancement of knowledge. As a basic science, astronomy uses the universe to test theories in the extremes of conditions that only the universe can provide, exceeding what can be done in laboratories by many, many orders of magnitude. Contributing to the big, though not terribly expensive, science of astronomy adds to national prestige, by way of enhancing our image as a technologically advanced nation.

The Parkes Observatory has attracted world-famous astronomers, and been used by two generations of astronomers embarking on careers —a number of whom are now Directors of other observatories in the world.

Social Value: Public interest

The excitement associated with scientific breakthroughs almost always extends from the scientific community to the general public, and stimulates awareness and interest in the science. Radio astronomy successes at Parkes provide tangible evidence of the high quality of Australian technology and expertise. Such widely-publicised successes attract the admiration, and one hopes the participation, of the best young Australian minds to a career in science.

To cater for the great public curiosity about the telescope and topical news in astronomy, the Parkes Observatory has a Visitor's Information and Education Centre. This centre broadcasts to Australians and overseas visitors that Astronomy is worth doing, that Australia has always done it well, that part of CSIRO excels at radio astronomy, and that we share our knowledge with the world. The Visitors' Centre receives about 55,000 students and adults each year. Pictured below are some of the facilities for visitors.



Social Value: Community Association

Embraced by the local community generally, and by the Shire Council and town businesses in particular, likenesses of the Parkes Radio Telescope appear on the logos of many motels, newspapers and businesses, the Council emblem, badges and promotional materials.

The telescope and its Visitors Centre accommodate many good-will inspection requests. The visits are recorded in the telescope's visitors' book.

It is continually acknowledged that the telescope adds to the town of Parkes' prestige and national identity, and further adds to the tourist dollars flowing into the town.

Landscape Value: The structure of the telescope is literally outstanding —though more hidden by trees than it was in 1961. The NSW Dep't of Forestry selected and planted native trees, to provide aesthetic relief and important windbreaks. Contemporary images show a rich variety of greenery; a complete contrast with the early desolation.

Rarity/representativeness/uniqueness: The Parkes Radio Telescope is still the biggest dish in the southern hemisphere dedicated to radio astronomy. From the moment of its conception in the early 50s, its value to the world astronomical community was abundantly obvious, so much so, that the Carnegie and Rockefeller Foundations put substantial amounts of money to ensure the project went ahead.

SOURCE	AMOUNT ($US)	YEAR
Carnegie Foundation	250,000	1954
Rockefeller Foundation	250,000	1955
Rockefeller Foundation	130,000	1959
Private Donors (Australia)	30,000	
Matching funds (Federal Government)	660,000	1954-59
Additional funds (Federal Government)	110,000	1959
TOTAL	1,420,000	

From its first moments, the Parkes antenna had a positional and technological advantage. The modern flavour in astronomy is to build large networks of smaller antennae, so it is very probable that the likes of Parkes shall never be built again.

Historic value: *After the Harbour Bridge and the Sydney Opera house, the Parkes radio telescope is the next most publicised structure in Australia* (ref 11).

SCIENTIFIC LANDMARKS

Discoveries of new lands always lead to production of maps, maps showing the major features, natural resources and wealth to be gained. So it was with discovering the southern sky with greater sensitivity, higher resolution and newer technologies at the Parkes Radio Telescope. In astronomy, catalogues are the product of mapping, and the Parkes Observatory has produced three major catalogues —the latest being at a higher frequency yet again (4.8 GHz) in the early 90s. It is during the compilation of these partially-completed catalogues containing curious new features, that astronomers must determine what is the best scientific option for investigation next. There has never been a shortage of choice.

Radio waves are often found to be at least partly polarised, either linearly or right and left circularly. It was from Parkes that the Faraday rotation of polarised cosmic radio waves was first discovered and reported to the world. This resulted, in part, from the foresight to

leading to the discovery and investigation of the magnetic field of the Milky Way galaxy. Polarisation studies persist to this day.

Very compact radio sources known as *quasars* needed an optical identification to examine their spectra. The first quasar to be precisely located, 3C 273, was done from Parkes using the moon as an occulting edge, in 1962. Examination of the diffraction pattern located the quasar to an accuracy sufficient to allow an optical identification. A spectrum was then obtained at Mt Palomar, and the enigma of quasars was launched on the astronomical world. For over two decades there was no explanation of how such objects could look like a star but emit the energy of a thousand galaxies.

The spiral structure of our Milky Way galaxy was deduced from observations taken at Parkes —something which optical telescopes were incapable of providing since inter-stellar dust blocks the visible light from all but the nearest parts of our galaxy.

In the late 70s, Parkes was used to discover emission lines from many organic molecules in space, some very similar to amino acids — the very building blocks of life.

In 1982, the quasar PKS 2000-330 from the Parkes catalogue, was identified as the most distant quasar then known, with a red shift of 3.78 corresponding to a distance of 20,000 million light years.

Over half the known pulsars have been discovered at Parkes, including two eclipsing binary systems, one of which is being used to test predictions from Einstein's Theory of General Relativity. The trace of the first pulsar recorded at Parkes appears on the back of the $50 note.

The Parkes antenna has been enlisted to help in a number of space exploration missions of world-wide interest: from NASA moon-missions —Apollo 11 being the most admired for Parkes' coverage of the first moon walk (1969) — to Voyager 2's encounter with Uranus (1986) and Neptune (1989), and the European Space Agency craft GIOTTO encounter with Comet Halley (1986), the PROJECT PHOENIX search for extra-terrestrial intelligence (1995), and the Galileo encounter with Jupiter destined for 1996. Each of these occasions has focussed world attention on Australian expertise and engineering, and re-couped either equipment upgrades or significant financial benefits.

ASSESSMENT OF HERITAGE SIGNIFICANCE

At the opening ceremonies in 1961, Chief of CSIRO Division of Radiophysics, EG "Taffy" Bowen, referred to the human condition to inquire:

". . . What shall we find and what purpose will it serve? If we knew what we would find, we would not be looking. Over the years there have been many theories and much speculation about the nature and origin of the universe, but there is very little evidence of a factual nature. There are, in fact, many more questions than there are answers. We do not know whether the universe is bounded, or whether it reaches to infinity in every direction; whether it has a beginning and an end, or whether it will have a perpetual existence; whether there are intelligent beings on other planets. The questions go on and on and it is our profound belief that this instrument and instruments like it are the ones which will reveal the ultimate truth about our universe.

If we do not at present know the answer to these questions, we certainly know where we should look. In the first place the telescope will be used to study in much greater detail those parts of the universe already known to us in a crude way –the planets of our solar system, our local galaxy and the nearer external galaxies. But the really exciting task will be to explore the most distant reaches of the universe, far beyond the range of any previous instruments, radio or optical, and at distances which have never yet been probed by mankind. The signals of these regions will have travelled five thousand million years or more before reaching us –signals which began their journey before this earth of ours even existed. In this way we shall be looking back into the history of the universe itself and so may discover how it had its origin and how it all began.

It has been truly been said that the search for truth is one of the noblest aims of mankind and there is nothing which adds to the glory of the human race or lends it such dignity as the urge to bring the vast complexity of the universe within the range of human understanding".

We see no reason to add a word, nearly 35 years later.

* * *